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Issued March 18, 1913.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF SOILS—BULLETIN No. 95.

MILTON WHITNEY, Chief.

THE UTILIZATION OF ACID AND BASIC SLAGS IN THE MANUFACTURE OF FERTILIZERS.

BY

WILLIAM H. WAGGAMAN,

Scientist in Fertilizer Investigations.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Soils,
Washington, D. C., October 7, 1912.

Sir: I have the honor to transmit herewith the manuscript of an article entitled "The Utilization of Acid and Basic Slags in the Manufacture of Fertilizers," by William H. Waggaman, scientist in fertilizer investigations of this bureau. This article embodies the results of analyses of domestic slags and of experiments in the preparation of slag in the laboratory, using rocks bearing potassium and phosphorus mixed with slags. Vast quantities of slag from the manufacture of steel are now discarded as worthless, and also enormous quantities of low-grade phosphate rock are now thrown away at the mines and are in danger of becoming a permanent loss. The work in this laboratory indicates that it may be possible by mixing phosphatic limestone and feldspar with the molten slag to produce a slag of value as a commercial fertilizer.

Very respectfully,

Milton Whitney,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE UTILIZATION OF ACID AND BASIC SLAGS IN THE MANUFACTURE OF FERTILIZERS.

INTRODUCTION.

In the course of this bureau's investigations of the fertilizer resources of the United States the possible utilization of the waste products from various industrial processes is receiving serious attention. One of the most important of these by-products, which is at present regarded as so much waste, is the slag produced in the manufacture of iron and steel.

The disposal of this slag has indeed become quite a problem, for though small quantities are consumed in the manufacture of cement, brick, and mineral wool, and larger quantities for roofing materials, road building, and railroad ballast,[1] the vast bulk of the slag produced in this country is thrown away. In the vicinity of many of the plants all the space available for dumping purposes has been utilized, and in order to dispose of the molten slag a haul of half a mile or more is frequently necessitated.

In foreign countries, particularly in Germany, where the iron ores used are high in phosphorus and the basic Bessemer process for the manufacture of steel is largely used, the slag produced is rich in phosphoric acid and therefore finds a ready market as a fertilizer.

The iron ores used in this country, however, with the exception of some mined in Alabama, are very low in phosphorus and consequently give slags containing, as a rule, considerably less than 1 per cent of phosphoric acid.

The three processes chiefly employed in this country for the manufacture of steel are the acid open-hearth method, the basic open-hearth, and the acid Bessemer process. The basic Bessemer process, which was devised for the purpose of handling ores high in phosphorus, is but little used in the United States.

It is only by the two basic processes that phosphorus is eliminated from the iron. These processes depend on the addition of large quantities of lime or limestone to slag off the impurities. Lime, having a great affinity for phosphorus, seizes this element, producing highly basic phosphatic compounds or solid solutions.

[1] Eckel, Bul. 213, U. S. Geol. Survey, 1903.

SOURCE AND AVAILABILITY OF PHOSPHORIC ACID IN BASIC SLAG.

The active or available phosphoric acid in basic slag has been regarded by many investigators as being derived from tetra-calcium phosphate ($Ca_4P_2O_9$). Crystals in the form of rectangular tablets, which showed on analysis a composition closely approximating the above formula, have actually been isolated[1] from basic slag.

Both Hilgenstock and Carnot,[2] however, found that different types of crystals followed in regular sequence in the bath and that toward the end of the operation, when the bath was richer in silica, blue crystals having the composition $P_2O_5SiO_25CaO$ were found.

Later investigations have shown that in slags of the same phosphate content those rich in silica were the most soluble in weak organic solutions. It is therefore probable that the so-called available phosphoric acid of slags is combined or forms a solid solution[3] with both silica and lime.

Campbell[4] states that in the manufacture of steel by the basic Bessemer process the final slag should contain from 40 to 50 per cent of lime and 5 to 6 per cent of silica, and though the silica may in some cases run higher, the phosphoric acid is then usually in a less soluble condition. Further on, in describing open-hearth practice, the same author[5] states that with good stock the cinder (slag) may contain as high as 20 per cent of silica and still be capable of eliminating the impurities from pig iron, but when much phosphorus is to be removed the silica must sometimes be as low as 12 per cent.

Although a high content of lime in the bath is important for the complete elimination of phosphorus from steel, it does not necessarily follow that the phosphorus in the resulting slag is readily soluble in solutions of organic acids or salts. Fluidity of slag is a very important factor in bringing about the reactions necessary to render the phosphatic slag soluble in aqueous solutions of organic acids or salts. The viscosity of a basic slag increases as the percentage of lime and magnesia are increased. Iron, silica, and manganese, on the other hand, impart fluidity to a slag.

Basic slag is not soluble to any extent in water, but excellent results have been obtained from its use, and it has been pretty well demonstrated that the phosphoric acid contained therein can be readily taken up by growing crops.

E. Reis and Arens[6] and others showed that the phosphoric acid in basic slag and in crystals of tetra-calcium phosphate was fairly

[1] Fritsch, Manufacture of Chemical Manures, 1911, p. 204; Wiley and Krug. Jour Anal. Chem., vol. 5, p. 685, 1891; Otto, Chem. Zeit., vol. 11, p. 255, 1887.

[2] Ibid., p. 205.

[3] Cameron and Bell, Bul. 41, Bureau of Soils, U. S. Dept. of Agriculture, 1907.

[4] Manufacture and Properties of Iron and Steel, p. 119.

[5] Ibid., p. 211.

[6] J. Fritsch, Manufacture of Chemical Manures, 1911, p. 209.

soluble in water saturated with carbon dioxid, but that the phosphoric acid in phosphorites and bone ash was very slightly soluble in the same medium. Fritsch,[1] in working with both basic slag and natural phosphorite, found that the former yielded nearly all its phosphoric acid to dilute solutions of citric and oxalic acids, but that the phosphorite was almost insoluble in such solutions.

The conventional method for determining the availability of phosphoric acid in basic slag is that described by Wagner, and consists in shaking 5 grams of finely ground slag in 500 c. c. of 2 per cent citric acid for one-half hour and then determining the amount of phosphoric acid thus dissolved. A slight modification of this method has been adopted by the American Association of Official Agricultural Chemists. It is claimed that the Wagner method shows an availability in accord with the actual crop yields obtained in the field, and some data [2] have been presented to prove this claim, although it is seriously questioned by some authorities that any quantitative relation is or can be established.

THE ENRICHMENT OF SLAGS.

The phosphoric acid in practically all of the slag produced for fertilizer purposes is derived from the iron and iron ore used. The basic slag after it is drawn from the furnace or poured from the converter seldom receives any subsequent treatment to enrich it in phosphoric acid or other fertilizer constituents. Hot sand is frequently added,[3] but this is to increase the "availability" [4] of the phosphoric acid already present in the slag.

Before basic slag was known to have a fertilizer value various methods were proposed to render the phosphoric acid contained therein available for fertilizer purposes. Scheibler [5] suggested the preparation of a precipitate by treating the slag with hydrochloric acid and then precipitating the phosphoric acid thus dissolved with milk of lime. Francke [6] recommended the decomposition of basic slag with magnesium chlorid, thus converting the phosphoric acid into magnesium phosphate. G. Meyer advocated the treatment of fused basic slag with an equal weight of acid potassium sulphate. Fritsch [7] suggested silicate of potash as a substitute for potassium sulphate in this last method.

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[1] J. Fritsch, Manufacture of Chemical Manures, 1911, p. 210.

[2] Maercker, Chem. Zeit., *63*, 1895; Peter, J., Evolution of the Citric Method for Available Phosphoric Acid in Thomas Phosphate Powder. London, 1908; Leavens, G. D. Discussion of Methods for Determining the Availability of the Phosphoric Acid in Thomas Phosphate. See also Bul. No. 107, Bureau of Chemistry, U. S. Dept. Agr., Official and Provisional Methods of Analysis.

[3] Wagner, P., Dungungsfragen, vol. 1, p. 28.

[4] I. e., solubility in solutions of organic electrolytes.

[5] German Patents 24130 and 25020.

[6] German Patent 27106.

[7] Manufactures of Chemical Manures, 1911, p. 207.

Scheibler's patent 34416 (German) describes a process for making a slag very rich in phosphoric acid. It consists in adding lime to the converter at two stages of the blow. The first slag run-off contains a very high percentage of phosphoric acid (sometimes as high as 24 per cent), while the slag produced from the second addition of lime is used over again in reducing the next charge of iron. Fritsch [1] states that phosphatic chalk is sometimes used in the converter instead of lime, thus increasing the quantity of phosphate in the slag. This appears to be an excellent plan and could no doubt be economically practiced in the United States, since our supplies of highly phosphatic limestone are practically inexhaustible. It would, however, be somewhat difficult to overcome the prejudice against any procedure in which a phosphorus-bearing substance is added to the bath.

Not only are there vast deposits of phosphate rock and phosphatic limestone in the United States, but there are also enormous quantities of potash feldspar which require only a cheap method of extracting the potash to render them available for fertilizer purposes. Various methods for treating feldspar have been proposed and patented,[2] and some of them are reported as successful, but in most of them the cost of labor, materials, and manipulation involved exceeds the value of the potash obtained, and, as Ross [3] states, "it is hardly likely in view of the comparatively low percentage of potash in all silicate rocks that any process can be devised which will prove so simple that the value of the potash alone will pay for its extraction."

There is, however, in the slag produced at steel works an immense amount of heat energy which is daily being lost.[4] As the slag flows like sirup from the furnaces or converters at a temperature of 1,800° C. it is in an excellent condition for dissolving either siliceous or basic minerals. It was with a view to utilizing this amount of waste energy to convert the phosphoric acid and potash of phosphorites, phosphatic limestones, and feldspar into an available form that the experiments hereinafter described were undertaken.

ACID OPEN-HEARTH SLAG AND PHOSPHATIC LIMESTONE.

An acid open-hearth slag from the National Steel Casting Co., of Montpelier, Ind., and a highly phosphatic limestone from Hickman County, Tenn., were used in the first experiments. The analyses of these materials are given in Tables I and II:

[1] Manufactures of Chemical Manures, 1911, p. 207.
[2] Ross, W. H., Circ. 71, Bureau of Soils, 1912.
[3] Circ. 71, Bureau of Soils, 1912.
[4] Ser. U. S. patent No. 996132 for utilizing heat of slag.

TABLE I.—*Analysis of acid open-hearth slag from National Steel Casting Co., Montpelier, Ind.*

Constituent.	Per cent.
SiO_2	50.26
Al_2O_3	.....
FeO	32.80
MnO	15.10
CaO	1.00
MgO	.....
TiO_2	0.32

TABLE II.—*Approximate analysis of phosphatic limestone from Hickman County, Tenn.*

Constituent.	Per cent.
$SiO_2Al_2O_3$	8.99
CaO	51.54
CO_2	17.20
P_2O_5	22.27

These ingredients were separately ground and then mixed in several different proportions. Each mixture was transferred to a graphite crucible and heated for about one hour in a muffle furnace. The resulting slag was then emptied out, cooled, ground to pass a 130-mesh sieve, and 2.5 gms. weighed out and made up to 250 c. c., with 2 per cent citric acid. The solution was shaken for one-half hour, and the phosphoric acid dissolved then determined. The results of these analyses are given in Table III.

TABLE III.—*Properties and phosphate content of melts obtained by fusing together acid slag and phosphatic limestone.*

Sample number.	Slag used.	Lime-stone used.	Proper-ties of fusion.	P_2O_5 soluble in citric acid.	Total P_2O_5.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
1–S	32.00	68.00	Viscous.	2.27	15.05
2–S	50.00	50.00	Limpid.	12.00	12.00
3–S	40.00	60.00	Viscous.	1.48	13.20

An inspection of Table III shows that equal parts of phosphatic limestone and acid slag produced a limpid slag in which all of the phosphoric acid was soluble in 2 per cent citric acid. The composition of this slag is shown in Table IV:

TABLE IV.—*Composition of slag produced by fusing together equal parts of acid slag and phosphatic limestone.*

Constituent.	Per cent.	Constit-uent.	Per cent.
SiO_2	33.59	MnO	8.89
CaO	26.35	P_2O_5	11.13
FeO	19.22	TiO_2	.19

The silica content of this slag is quite high and the lime content much lower than it is in ordinary basic slag, which usually contains from 2.5 to 20 per cent of silica (SiO_2) and from 40 to 50 per cent of lime (CaO). This only bears out, however, what has previously been stated regarding the availability of phosphoric acid in highly siliceous basic slags. It would no doubt have been possible to obtain a slag richer in available phosphoric acid by increasing somewhat the percentage of phosphatic limestone in the melt, but this limestone was all consumed in the following experiments.

ACID OPEN-HEARTH SLAG, PHOSPHATIC LIMESTONE, AND FELDSPAR.

The same acid slag and phosphatic limestone were used in these experiments, but in addition a rather pure orthoclase containing 13.72 per cent K_2O was employed. The mixtures were treated in graphite crucibles, and the cooled melts ground and shaken with 2 per cent citric acid. The solutions were analyzed both for P_2O_5 and for K_2O, and the results are given in Table V.

TABLE V.—*Properties and analysis of melts obtained by fusing together acid slag, phosphatic limestone, and feldspar.*

Sample number.	Amount of material used.			Properties of fusion.	P_2O_5 soluble in citric acid.	Total P_2O_5.	K_2O soluble in citric acid.	Total K_2O.
	Slag.	Phosphatic limestone.	Feldspar.					
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
4–S	30.9	38.2	30.9	.....	2.56	8.31	1.36	4.29
5–S	35.3	29.4	35.3	Viscous	2.14	7.91	1.04	4.84
6–S	30.0	25.0	45.0	Very viscous	2.48	6.72	.50	6.17
8–S	27.3	45.4	27.3	Viscous	3.88	12.21	1.66	3.74
9–S	36.0	40.0	24.0	Limpid	5.93	10.76	1.95	3.29
10–S	24.0	40.0	36.0	Very viscous	2.46	10.76	1.75	4.93
13–S	40.1	33.2	26.7	Viscous	.....	8.93	.81	3.66
14–S	31.1	43.0	25.9	Slightly viscous	1.11	11.56	3.02	3.55
15–S	40.4	37.2	22.4	.....do	1.68	10.00	1.46	3.06
18–S	37.6	38.9	23.5	.....do	1.92	10.46	1.87	3.22

Only in the case of a few samples (Nos. 8–S, 9–S, 14–S, 18–S) were melts obtained which contained a sufficient quantity of either phosphoric acid or potash soluble in citric acid (2 per cent) to make them of any interest from a fertilizer standpoint. None of the melts, with the exception of No. 9–S, is high enough in both phosphoric acid and potash (citric soluble) to be of interest commercially.

From the results obtained on basic slags, however, which are described later in this paper, it is thought that in most of these experiments with acid slag the temperature of the furnace was not sufficiently high to produce good fusions. The supplies of both air and gas fluctuated considerably, and in only one instance (No. 9–S) was a limpid melt obtained.

In Table VI the composition of some of the melts is given, and it will be readily seen that the slight difference in the proportions of the various oxids in these melts would hardly account for the wide differences in the percentages of citric-soluble phosphoric acid and potash, unless the fusions, and consequently the reactions, were incomplete.

TABLE VI.—*Composition of basic slags produced by fusing together acid slag, phosphatic limestone, and feldspar.*

Constituent.	Proportion contained in—			
	No. 9S.	No. 14S.	No. 15S.	No. 18S.
SiO_2	38.17	37.29	39.04	38.53
Al_2O_3	4.42	4.77	4.12	4.32
FeO	11.80	10.20	13.25	12.33
CaO	25.26	27.07	23.72	24.58
MnO	5.44	4.70	6.10	5.68
TiO_2	.12	.10	.13	.12
K_2O	3.29	3.55	3.06	3.22
Na_2O	.53	.57	.49	.52
P_2O_5	10.76	11.56	10.00	10.46

PHOSPHATIC LIMESTONE AND FELDSPAR.

Attempts were made to fuse together or cause reactions to take place at high temperatures between phosphatic limestone and feldspar. Some melts were obtained which were very viscous and not very uniform in appearance. The results of these experiments are given in Table VII.

TABLE VII.—*Properties and analysis of melts obtained by heating together phosphatic limestone and feldspar.*

Sample No.	Proportion of—		Properties of fusion.	P_2O_5 soluble in citric acid.	Total P_2O_5.	K_2O soluble in citric acid.	Total K_2O.
	Feldspar.	Phosphatic limestone.					
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
7S	54.8	45.2	Very viscous	2.21	11.86	2.94	7.51
11S	61.7	38.3	Would not fuse.	2.20	10.30	Less than 1 per cent.	8.45
12S	60.0	40.0	Very viscous	1.15	10.76	1.86	8.32
16S	52.0	48.0	do	Not determined.	12.90	Not determined.	5.76
17S A	42.1	57.9	do	do	15.56	do	5.80
17S B	50.2	49.8	do	do	13.39	do	6.88
17S C	53.1	46.9	do	do	12.61	do	7.27
17S D	55.6	44.4	do	do	11.94	do	7.62
17S E	57.1	42.9	do	do	11.54	do	7.82
17S F	58.5	41.5	do	do	11.16	do	8.01
17S G	59.8	41.2	Less viscous	1.70	10.53	1.96	8.20

All the melts obtained in these experiments were quite viscous, and none contained enough citric-soluble phosphoric acid and potash to make them of any value.

In Table VIII the composition of two of these slags is given. It will be noticed that they do not differ greatly from those obtained by mixing the phosphatic limestone and feldspar with acid open-hearth slag. The absence of iron and manganese, however, may account in some measure for the difficulty encountered in fusing phosphatic lime and feldspar.

TABLE VIII.—*Composition of slags produced by fusing together phosphatic limestone and feldspar.*

Constituent.	No. 7 S.	No. 17 SG.
	Per cent.	*Per cent.*
SiO_2	40.89	43.67
Al_2O_3	10.08	11.02
CaO	28.13	24.98
K_2O	7.51	8.20
Na_2O	1.21	1.32
P_2O_5	11.86	10.53

BASIC SLAG, PHOSPHATE ROCK, AND FELDSPAR.

In these experiments a basic open-hearth slag from Reubling, N. J., a high-grade phosphate rock from Mount Pleasant, Tenn., and the feldspar used in the previous experiments were employed. The muffle furnace in which the fusions were made was moved to another room, where the flow of gas was better and the pressure of the blast was more constant. The experiments were therefore carried on under more uniform conditions and at a higher temperature.

The composition of the basic open-hearth slag and phosphate rock used are given in Tables IX and X.

TABLE IX.—*Composition of phosphate rock (burned) from Mount Pleasant, Tenn.*

Constituent.	Per cent.
SiO_2	6.12
$Fe_2O_3Al_2O_3$	4.44
CaO	53.05
P_2O_5	36.38

TABLE X.—*Analysis of basic open-hearth slag from Reubling, N. J.*

Constituent.	Per cent.
SiO_2	28.78
Al_2O_3	5.60
Fe_2O_3	17.40
MnO	7.70
CaO	33.82
MgO	4.70
TiO_2	.48
P_2O_5	.....
SO_3	.90

The slag, phosphate rock, and feldspar were ground, mixed, fused, and treated as described in the experiments on acid slag. The results are given in Table XI.

TABLE XI.—*Properties and analysis of melts obtained by fusing together basic open-hearth slag, phosphate rock, and feldspar.*

Sample number.	Proportion of materials used.			Properties of fusion.	P_2O_5 soluble in citric acid.	Total P_2O_5.	K_2O soluble in citric acid.	Total K_2O.
	Slag.	Phosphate rock.	Feldspar.					
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
19S	68.1	31.9	.....	Limpid	6.52	11.61	.....	.....
20S	63.9	36.1	.....	do	3.20	13.13	.....	.....
21S	52.3	27.3	20.4	do	5.28	9.94	2.71	2.79
22S	45.8	28.8	25.4	Limpid fusion, completely soluble in citric acid (2 per cent).	7.89	10.46	2.78	3.49
23S	45.7	23.9	30.4	Slightly viscous	4.05	8.68	3.33	4.17
24S	48.1	25.2	26.7	Limpid	7.52	9.17	3.83	3.66

This table shows that a large part both of the potash and phosphoric acid can be rendered soluble in a citric-acid solution by fusing together certain proportions of basic slag, phosphate rock, and feldspar. In the case of No. 22S over 75 per cent of the phosphoric acid present in the melt and nearly 80 per cent of the potash was dissolved by 2 per cent citric-acid solution, and in the case of No. 24S, 82 per cent of the phosphoric acid and all of the potash was rendered soluble in the same medium.

The composition of the melts obtained is given in Table XII. It will be noticed that the melts containing the highest precentage of citric-soluble phosphoric acid and potash contain from 30 to 33 per cent of silica and from 30 to 32 per cent of lime with 8 to 9 per cent of ferric oxide and 3.5 to 4 per cent of manganese oxide.

TABLE XII.—*Composition of slags produced by fusing together basic slag, phosphate rock, and feldspar.*

Constituent.	Proportion contained in sample.				
	No. 19S.	No. 20S.	No. 22S.	No. 23S.	No. 24S.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	21.55	20.59	30.10	31.66	32.92
Al_2O_3	5.23	5.14	7.89	8.43	8.72
Fe_2O_3	11.90	11.17	9.15	8.01	8.49
CaO	39.95	40.76	32.19	30.74	29.64
MgO	3.20	3.00	2.25	2.15	2.27
MnO	5.24	4.92	4.03	3.53	3.70
TiO_2	.32	.31	.25	.22	.23
K_2O	.....	.....	2.79	4.17	3.66
Na_2O	.....	.....	.45	.67	.59
P_2O_5	11.61	13.13	9.94	8.68	9.17
SO_3	.61	.58	.47	.41	.43

CONDITION OF POTASH IN THE MELTS.

Although citric-soluble phosphoric acid is often regarded as having a fertilizer value nearly equal to that of the water-soluble phosphates,[1] the same view is not taken of potash-bearing substances.

The potash from the Stassfurt mines, Germany, which at present furnish almost the entire supply of the United States, the potash of wood ashes and wool washings and that contained in the giant kelps off our western coast are all soluble in water, while it has been repeatedly shown that the potash of feldspar is almost insoluble in water and but slightly soluble in the mineral acids.

The data regarding the value of finely ground feldspar as a fertilizer are very conflicting, so much so, in fact, that it is unwise to depend on this material for a potash fertilizer.

It was first thought that potassium pyrophosphate ($K_4P_2O_7$) was formed by fusing the feldspar in a medium containing highly basic phosphatic compounds. Potassium pyrophosphate, however, is soluble in water, whereas the melts obtained as described above contained but a trace of water-soluble potash. Their solubility in water saturated with carbon dioxid, however, was quite appreciable.

Whether the potash in these melts will prove beneficial to crops remains to be tested by actual experiment, but it is reasonable to suppose that it will be much more soluble under soil conditions than the ordinary potash minerals of the soil.

COST OF MANUFACTURING SLAG FERTILIZER.

The cost of manufacturing slag containing both potash and phosphoric acid would be but little greater than the actual cost of the raw materials plus freight charges. It would be necessary, perhaps, to heat both the feldspar and phosphate rock before adding them to the molten slag in order to avoid the cooling and consequent congealing of the latter, but both the labor and expense involved should be comparatively slight.

A conservative estimate of the cost of materials (f. o. b. at the mines) and labor, and the expense of grinding a product such as number 24S, is given in Table XIII:

TABLE XIII.—*Cost of manufacturing 1 ton of slag of the composition found in No. 24 S.*

Item.	Cost.
Feldspar, 534 pounds, at $4.50 per ton	$1.21
Phosphate rock, 500 pounds, at $3 per ton	.75
Slag (basic), 966 pounds	.....
Labor	.50
Cost of grinding	.50
Total	2.96

[1] A report of a conference of the experiment stations of New England, New York, and New Jersey, Mar. 1, 1911, indicates that citrate-soluble phosphoric acid has about nine-tenths of the fertilizer value of water soluble phosphoric acid.

WHEAT PLANTS GROWN IN NORFOLK FINE SAND WITH VARIOUS FERTILIZER TREATMENTS.

1. Check.
2. Acid phosphate 200 pounds to acre.
3. Tennessee ground phosphate 200 pounds to acre.
4. Basic slag, feldspar, and phosphate 200 pounds to acre.
5. Calcined phosphate 200 pounds to acre.

Assigning to the citric-soluble phosphoric acid the value usually given, and to the citric-soluble potash three-fourths of the value given to water-soluble potash, we obtain the following values for the actual fertilizer constituents:

TABLE XIV.—*Value of fertilizer constituents contained in 1 ton of slag No. 24 S.*

Item.	Cost.
7.50 per cent phosphoric acid, 150 pounds, at 2½ cents per pound	$3.75
3.82 per cent potash, 76 pounds, at 2½ cents per pound	1.90
Total	5.65

The vast bulk of orthoclase available in this country, however, does not contain over 8 per cent of potash or about two-thirds of the quantity contained in the feldspar used in these experiments. Modifying, therefore, the potash value given in Table XIV to more nearly what could be expected from the average feldspar, we get the following values:

TABLE XV.—*Value of fertilizer constituents contained in 1 ton of slag No. 24 S when orthoclase containing 8 per cent of potash is used.*

Item.	Cost.
7.50 per cent phosphoric acid, 150 pounds, at 2½ cents per pound	$3.75
2.55 per cent potash, 51 pounds, at 2½ cents per pound	1.28
Total	5.03

The price of a mixed fertilizer having the composition 8 per cent of phosphoric acid, 2 per cent of ammonia, and 2 per cent of potash, varies, in the present market, from $18 to $20 a ton. If such a fertilizer be made up of the most costly fertilizer materials the market value of the actual phosphoric acid, potash, and nitrogen contained therein is about $11.22, leaving a surplus of $7.78 for fixed charges and freight, and to cover the cost of the filler, and of mixing, bagging, tagging, and marketing the goods. Any surplus over and above these expenses is the manufacturers' profit.

The expense attached to the production of a slag fertilizer having the value given in Table XV would be such that the material could probably be sold at a small profit on the basis of the market value of the fertilizer constituents alone.

Adding, however, one-third of the amount charged to defray the cost of an 8–2–2 mixture prepared from high-grade raw materials, we obtain the figure $7.62 for the selling price. This should yield the manufacturer a reasonable profit.

RESULT OF POT TESTS WITH SLAG FERTILIZERS.

In order to test the fertilizer value of the product obtained by fusing together phosphate rock, slag, and feldspar a few preliminary experiments were undertaken. While the results are far from conclusive, they are favorable and indicate that good results are to be expected from the use of such a fertilizer.

The experiments were conducted by Mr. J. J. Skinner, of this bureau, by the wire basket or paraffin pot method described in Circular No. 18, Bureau of Soils, and using wheat seedlings. Two types of soil were employed, namely, the Norfolk fine sand and the Portsmouth silt loam. Each of these soils was treated with applications of the slag fertilizer, and wheat seedlings planted therein. The plants were grown for a period of three weeks and then weighed and compared with those grown under similar conditions in untreated soil and in soil treated with various other forms of phosphatic fertilizers.

In Tables 16 and 17 the weight of the untreated plants or checks is taken as 100, and the weights of the plants grown under similar conditions, but in soil treated with various phosphatic fertilizers, are compared with this figure.

TABLE XVI.—*Relative weights of wheat plants grown for a period of three weeks in Norfolk fine sand untreated and treated with various quantities of phosphatic fertilizers.*

Treatment.	0 pounds per acre.	50 pounds per acre.	100 pounds per acre.	200 pounds per acre.	500 pounds per acre.	1,000 pounds per acre.	2,000 pounds per acre.	Average weight.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Check	100							100
Acid phosphate (16 per cent P_2O_5)		97	93	96	100	102	98	98
Tennessee raw rock phosphate (35 per cent P_2O_5)		104	108	120	124	134	124	119
Calcined phosphate		135	104	120	155	195	233	157
Basic slag, feldspar, and phosphate		131	116	116	126	128	146	127

TABLE XVII.—*Relative weights of wheat plants grown for a period of three weeks in Portsmouth silt loam untreated and treated with various quantities of phosphatic fertilizer.*

Treatment.	0 pounds per acre.	50 pounds per acre.	100 pounds per acre.	200 pounds per acre.	500 pounds per acre.	1,000 pounds per acre.	2,000 pounds per acre.	Average weight.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Check	100							100.0
Acid phosphate (16 per cent P_2O_5)		108	126	121	95	93	78	108.0
Tennessee raw rock phosphate		108	126	126	143	149	139	132.0
Calcined phosphate		92	105	116	126	139	176	125.7
Basic slag, feldspar, and phosphate rock		104	106	99	116	121	153	117.0

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